Syllabus
«Neuroscience» («Нейронаука»)
(8 ECTS)

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1. Course Description

a) Pre-requisites

No prerequisites

b) Abstract

"Neuroscience" is a basic course dealing with structure and functioning of the nervous system designed for the Master Program "Cognitive sciences and technologies: from neuron to cognition". Understanding basic principles of nervous system functioning is essential for the study of cognitive processes, since the latter intrinsically reside in brain functioning. Thus achieving a realistic understanding of the cognitive domain indispensably requires knowledge of basic features of the brain and principles of its functioning, its capacities, and limitations.

The introductory part of the course includes a short summary on the history of neuroscience and a comparative survey of methods employed in studying the nervous system. Then follows a short update on neuroanatomy and neurohistology. The course includes the following major topics: signal transmission and processing in the nervous system; sensory systems of the brain; motor systems of the brain; neurophysiological bases of integrative brain functions including sleep and arousal, emotions and memory.

The course "Neuroscience" is new and unique discipline within the educational programs of the National Research University Higher School of Economics. The course is based on contemporary scientific research in neuroscience and related scientific areas. It is essential in training competent specialist in the areas of cognitive sciences and technologies.

The author of the course Boris V. Chernyshev has significant teaching experience, including reading the following related courses at National Research University Higher School of Economics and at Moscow State University: "Essential neurobiology", "Physiology of the central nervous system", "Physiology of sensory systems", "Physiology of higher nervous activity",

"Social psychophysiology". The course implements several innovative authors' teaching techniques, including group discussions and two-choice tests.

2. Learning Objectives

Learning objectives of the course "Neuroscience" are to introduce students to the subject of neuroscience, its foundation and connections to other branches of knowledge:

- The role of the nervous system functioning in human psychological processes and behaviour;
- Methods of research in neuroscience applicable to the fields of psychology, social science and economics;
- Physiological mechanisms and restrictions applicable to psychological processes and behaviour.

3. Learning Outcomes

After completing the study of the course "Neuroscience" the student:

- knows basic notions and definitions in neuroscience, its connections with other sciences.
- knows the methods used for the study of the nervous system structure and functioning.
- knows the basic structure of the nervous system.
- knows the basic functions of the nervous system.
- is able to relate psychological phenomena to the structure and functioning of the nervous system.
- is able to distinguish the capacities and restrictions applied by brain structure and functioning to psychological processes.
- possesses skills for choosing appropriate neuroscience methods for psychological research.
- possesses skills for translation between psychological and physiological levels of interpretation of experimental data.

4. Course Plan

Topics:

№	Topic	Total hours	Class hours		Self-study	Assessment
			Lectures	Seminars		
1.	Basic concepts and methods of neuroscience	24	2	6	16	Written test (30 minutes).
2.	Structural organization of the nervous system	42	4	8	30	Written test (30 minutes).
3.	Neural signaling	70	6	14	50	Written test (30 minutes).
4.	Sensory systems	70	8	12	50	Written test (30 minutes).
5.	Motor systems	56	6	10	40	Written test (30 minutes).

№	Topic	Total hours	Class hours		Self-study	Assessment
			Lectures	Seminars		
6.	Integrative brain functions	42	6	6	30	Written test (30 minutes).
Total:		**304**	**32**	**56**	**216**	

Overview of the topics

TOPIC 1. BASIC CONCEPTS AND METHODS OF NEUROSCIENCE

Subtopic 1.1. The subject and overview of basic concepts of neuroscience

The subject of neuroscience. The branches and fields of study within neuroscience. Basic levels in studying the nervous system. The nature of behaviour as a consequence of activity generated within the nervous system. Basic elements of the neural system structure. The mind-body problem. Metaphors of the brain; true and false corollaries of a computer metaphor.

Subtopic 1.2. Research methods of neuroscience

Distinction between the methods of studying behaviour and methods for studying the nervous system. Distinction between structural vs. functional methods, between methods in behaving and anaesthetized organisms, between non-invasive vs. invasive methods. Experiments in humans, other living organisms, reduced preparations and in computational models. Morphological, biochemical and physiological methods. The spectrum of physiological methods: lesions, stimulation, recording. Electrical, chemical, optogenetical, transcranial magnetic stimulation. Single-unit and multiple-unit recording. Patch clamp and voltage clamp methods. Optical recording. Near-infrared spectroscopy. Structural and functional brain scanning. Electroencephalography and magnetoencephalography.

TOPIC 2. STRUCTURAL ORGANIZATION OF THE NERVOUS SYSTEM

Subtopic 2.1. Basic Layout of The Nervous System and Gross Anatomy

Neurons and fibers in the nervous system. Ontogenesis of the nervous system: neural tube, brain vesicles. Neuronal growth and establishing synaptic connections between neurons. Basic subdivisions of the central nervous system. Anatomical planes of section and anatomical coordinates.

Lobes of the cerebral cortex. Major gyri and sulci of the cerebral cortex. Brodmann areas. Internal anatomy of the forebrain. Basal nuclei of the forebrain.

Diencephalon. Thalamus and thalamocortical relations. Hypothalamus. Hypophysis and epiphysis. Brainstem: midbrain, pons, medulla oblongata. Cranial nerves.

External anatomy of the spinal cord. Internal anatomy of the spinal cord. Spinal roots and spinal ganglia.

Blood supply of the brain and spinal cord. The blood-brain barrier. The meninges. The ventricular system. Peripheral nervous system

Subtopic 2.4. Histology and Cytoarchitectonics of the Nervous System

The cellular composition of the nervous system. Glia: basic cell types and their functions. Neurons: basic cell types, their anatomical location and functions. Basic parts of neurons: cell bodies, dendrites, axons, synapses. Layers of the cerebral cortex.

TOPIC 3. NEURAL SIGNALING

Subtopic 3.1. Electrical Signals of Nerve Cells

Electrical signals of nerve cells. Long-distance transmission of electrical signals. How ion movements produce electrical signals. Passive membrane properties. Forces that create membrane potentials. Nernst and Goldman equations. The ionic basis of the resting membrane potential. The ionic basis of action potentials.

Subtopic 3.2. Voltage-Dependent Membrane Permeability

Ionic currents across nerve cell membranes. Na+ and K+ voltage-dependent ionic currents and corresponding membrane conductances. Reconstruction of the action potential. Long-distance signaling by means of action potentials. Increased conduction velocity as a result of myelination.

Subtopic 3.3. Ion Channels and Transporters

Ion channels underlying action potentials. Toxins that poison ion channels. The diversity of ion channels. Voltage-gated ion channels. Ligand-gated ion channels. Stretch- and heat-activated channels. The molecular structure of ion channels. Active transporters create and maintain ion gradients. Diseases caused by altered ion channels. Functional properties of the Na+/K+ pump.

Subtopic 3.4. Synaptic Transmission

Electrical synapses. Signal transmission at chemical synapses. Properties of neurotransmitters. Criteria that define a neurotransmitter. Quantal release of neurotransmitters. Release of transmitters from synaptic vesicles. Local recycling of synaptic vesicles. The role of calcium in transmitter secretion. Molecular mechanisms of synaptic vesicle cycling. Diseases that affect the presynaptic terminal. Neurotransmitter receptors. Postsynaptic membrane permeability changes during synaptic transmission. Excitatory and inhibitory postsynaptic potentials. Summation of synaptic potentials.

Subtopic 3.5. Neurotransmitters and Their Receptors

Categories of neurotransmitters. Acetylcholine. Myasthenia gravis. Glutamate. GABA and glycine. The biogenic amines. Biogenic amine neurotransmitters and psychiatric disorders. ATP and other purines. Peptide neurotransmitters. Unconventional neurotransmitters. Neurotoxins that act on postsynaptic receptors.

Subtopic 3.6. Molecular Signaling within Neurons

Strategies of molecular signaling. The activation of signaling pathways. Receptor types. G-proteins and their molecular targets. Second messengers. Second messenger targets: protein kinases and phosphatases. Nuclear signaling.

Subtopic 3.7. Synaptic Plasticity

Short-term synaptic plasticity. Long-term potentiation at a hippocampal synapse. Mechanisms underlying LTP. Mechanisms underlying LTD.

TOPIC 4. SENSORY SYSTEMS

Subtopic 4.1. The Somatic Sensory System: Touch and Proprioception

Afferent fibers convey somatic sensory information to the central nervous system. Dermatomes. Somatic sensory afferents exhibit distinct functional properties. Mechanoreceptors specialized to receive tactile information. Mechanoreceptors specialized for proprioception. Central pathways conveying tactile information from the body: the dorsal column-medial lemniscal system. Central pathways conveying tactile information from the face: the trigeminothalamic system. Central pathways conveying proprioceptive information from the body. Central pathways conveying proprioceptive

information from the face. The somatic sensory components of the thalamus. Primary somatic sensory cortex. Patterns of organization within the sensory cortices: brain modules. Corticocortical and descending pathways. Plasticity in the adult cerebral cortex.

Subtopic 4.2. Pain

Nociceptors. Transduction and transmission of nociceptive signals. Central pain pathways and their distinction from mechanosensory pathways. Projected and referred pain. Parallel pain pathways. Pain and temperature pathways for the face. Other modalities mediated by the anterolateral system. Sensitization. Descending control of pain perception. Phantom limbs and phantom pain. The placebo effect. The physiological basis of pain modulation.

Subtopic 4.3. The Auditory System

Sound. The audible spectrum and auditory function. The external ear. The middle ear. Four causes of acquired hearing loss. Sensorineural hearing loss and cochlear implants. The inner ear. Hair cells and the mechanoelectrical transduction of sound waves. The ionic basis of mechanotransduction in hair cells. The cochlear amplifier. Tuning and timing in the auditory nerve. Auditory pathways through the brainstem. Integrating information from the two ears. Monaural pathways from the cochlear nucleus to the nuclei of the lateral lemniscus. Integration in the inferior colliculus. The auditory thalamus. The auditory cortex. Representing complex sounds in the brain.

Subtopic 4.4. The Vestibular System

Degrees of freedom of head movements. The vestibular labyrinth. Vestibular hair cells. Adaptation and tuning of vestibular hair cells. The otolith organs: the utricle and saccule. How otolith neurons sense tilts and linear accelerations of the head. The semicircular canals. How semicircular canal neurons sense angular accelerations. Central pathways for stabilizing gaze, head, and posture. Clinical evaluation of the vestibular system. Vestibular pathways to the thalamus and cortex. Spatial orientation, perception and multisensory integration.

Subtopic 4.5. Vision: The Eye

Anatomy of the eye. The formation of images on the retina. Myopia and other refractive errors. The surface of the retina. The macula lutea, fovea and foveola. The blind spot. Retinal circuitry. Retinal pigment epithelium. Phototransduction. Functional specialization of the rod and cone systems. Anatomical distribution of rods and cones. Cones and color vision. The importance of context in color perception. Retinal circuits for detecting luminance change. The perception of light intensity. Contribution of retinal circuits to light adaptation.

Subtopic 4.6. Central Visual Pathways

Central projections of retinal ganglion cells. The retinotopic representation of the visual field. Visual field deficits. Spatiotemporal tuning properties of neurons in primary visual cortex. Primary visual cortex architecture. Combining inputs from two eyes. Division of labor within the primary visual pathway. Binocular vision. The functional organization of extrastriate visual areas.

TOPIC 5. MOTOR SYSTEMS

Subtopic 5.1. Motor Neuron Circuits and Spinal Motor Control

Neural centers responsible for movement. Motor neuron-muscle relationships. The motor unit. The regulation of muscle force. The spinal cord circuitry underlying muscle stretch reflexes. The influence of sensory activity on motor behavior. Other sensory

feedback affecting motor performance. Flexion reflex pathways. Spinal cord circuitry and locomotion. The autonomy of central pattern generators.

Subtopic 5.2. Motor Control of the Brainstem and Spinal Cord

Organization of descending motor control. The corticospinal and corticobulbar tracts. Functional organization of the primary motor cortex. Motor maps. Patterns of facial weakness and their importance for localizing neurological injury. The premotor cortex. Motor control centers in the brainstem: motor systems that maintain balance, govern posture, and orient gaze. The reticular formation. The vestibular system. Muscle tone.

Subtopic 5.3. Modulation of Movement by the Basal Ganglia

Projections to the basal ganglia. Projections from the basal ganglia to other brain regions. Circuits within the basal ganglia system. Role of the basal ganglia in eye movements. Dopamine modulation basal ganglia circuits. Hypokinetic and hyperkinetic movement disorders. Parkinson's disease. Huntington's disease. Deep brain stimulation. Basal ganglia loops and non-motor brain functions.

Subtopic 5.4. Modulation of Movement by the Cerebellum

Organization of the cerebellum. Projections to the cerebellum. Projections from the cerebellum. Circuits within the cerebellum. Cerebellar circuitry and the coordination of ongoing movement. Consequences of cerebellar lesions.

Subtopic 5.5. Eye Movements and Sensory Motor Integration

What eye movements accomplish. The actions and innervation of extraocular muscles. The perception of stabilized retinal images. Types of eye movements and their functions. Neural control of saccadic eye movements. Sensory motor integration in the superior colliculus. Neural control of smooth pursuit movements. Neural control of vergence movements.

TOPIC 6. INTEGRATIVE BRAIN FUNCTIONS

Subtopic 6.1. Memory

Basic mechanisms of brain plasticity. Qualitative categories of human memory. Temporal categories of memory. Memory consolidation and priming. The importance of association in information storage. Conditioned learning. Savant syndrome. Forgetting. Brain systems underlying declarative memory. Acquisition and storage. An anatomical substrate for declarative memories. Brain systems underlying nondeclarative memory acquisition and storage. Memory and aging. Alzheimer's disease.

Subtopic 6.2. Emotions

Physiological changes associated with emotion. Facial expressions. The integration of emotional behavior. The limbic system. The importance of the amygdala. The relationship between neocortex and amygdala. Affective disorders. Cortical lateralization of emotional functions. Emotion, reason, and social behavior. Emotional reinforcement and addiction.

Subtopic 6.3. Sleep and Arousal. Consciousness.

Why do humans (and many other animals) sleep? The sleep styles of different species. The circadian cycle of sleep and wakefulness. Molecular mechanisms of biological clocks. Stages of sleep. Electroencephalography. Physiological changes in sleep states. Other possible functions of sleep and dreaming. Neural circuits governing sleep. Thalamocortical interactions in sleep. Sleep disorders. Consciousness.

5. Reading List

a) Required

Purves D., Augustine G.J., Fitzpatrick D., Hall W.C., LaMantia A.-S., White L.C. (eds.) Neuroscience, 5th edition. Sinauer Associates, 2012. - http://opac.hse.ru/absopac/index.php?url=/books/print_books_easy/

b) Optional

Squire L.R., Berg D., Bloom F. E., du Lac S., Ghosh A., Spitzer N. C. (Eds.). Fundamental Neuroscience, 4th ed. Academic Press, 2012. - http://opac.hse.ru/absopac/index.php?url=/books/print_books_easy/

Blumenfeld H. Neuroanatomy through Clinical Cases, 2nd edition. Sinauer Associates, 2010. - http://opac.hse.ru/absopac/index.php?url=/books/print_books/

6. Grading System

The final grade will be determined by the current grade ($\mathbf{G_{current}}$), the class grade ($\mathbf{G_{class}}$), the self-study grade ($\mathbf{G_{self\text{-}study}}$) and the exam grade ($\mathbf{G_{exam}}$).

The cumulative grade ($\mathbf{G_{cumulutive}}$) for the student's achievements during the course is calculated by the end of the course on the basis of the current grade, the class grade, and the self-study grade:

$$\mathbf{G_{cumulutive}} = 0.4 * \mathbf{G_{current}} + 0.3 * \mathbf{G_{class}} + 0.3 * \mathbf{G_{self\text{-}study}}.$$

The final grade ($\mathbf{G_{final}}$) is calculated on the basis of the cumulative grade and the examination grade:

$$\mathbf{G_{final}} = 0.5 * \mathbf{G_{cumulutive}} + 0.5 * \mathbf{G_{exam}}$$

The grades are rounded up arithmetically.

If the cumulative grade of a student equals 8, 9 or 10, the student can opt that the final grade be given equal to the cumulative grade:

$$\mathbf{G_{final}} = \mathbf{G_{cumulutive}}$$

If the student is eligible for this option, he/she has to inform the teacher about his/her decision concerning the final grade before the examination.

The final grade, which is the resultant grade for the course, goes to the certificate of Master's degree.

Table of Grade Correspondence

Ten-point Grading Scale	Five-point Grading Scale	
1 - very bad 2 – bad 3 – no pass	Unsatisfactory – 2	**FAIL**
4 – pass 5 – highly pass	Satisfactory – 3	**PASS**
6 – good 7 – very good	Good – 4	
8 – almost excellent 9 – excellent 10 – perfect	Excellent – 5	

Guidelines for Knowledge Assessment

The class grade is given by the teacher for attendance and activity during class hours.
The self-study grade is given by the teacher for the results of self-studies, which are assessed by way of written tests given during seminars.
The current grade is given by the teacher as an average grade for two mid-term control tests.
The examination grade is given by the teacher during the final examination.

Sample test questions:

Decide whether the statement is true or false:
1. Neuroscience is an interdisciplinary science dealing with the structure and functioning of the nervous system.
2. Behaviour is an active interaction of the organism with the external world mediated by the activity of the nervous system.
3. Immunochemical staining is a way to stimulate or suppress activity of living nerve cells.
4. Computerized tomography allows studying functional processes in the living brain.
5. Golgi method allows staining neurons including both the cell body and all its dendritic and axonal ramifications.
6. Near-infrared spectroscopy can be used for non-invasive assessment of brain function through the intact skull.
7. Magnetoencephalography offers worse temporal resolution than functional magnetic resonance imaging.

Written tests are written assignments involving open questions and two-choice questions. Each correct answer adds one point. The grade is calculated as the proportion of correct answers to the total number of questions (for multiple-choice questions). The

grade is calculated as the proportion of correct answers exceeding half of the total number of questions to half the total number of questions (for two-choice questions).

7. Examination Type

Oral examination

Final examination questions:

1. Research methods of neuroscience.
2. Anatomy of the cerebral cortex.
3. Anatomy of the diencephalon and the brainstem.
4. Histology and cytoarchitectonics of the nervous system.
5. Electrical potentials of nerve cells.
6. Voltage-dependent membrane permeability.
7. Ion channels.
8. Synaptic transmission.
9. Neurotransmitters and their receptors.
10. Molecular signaling within neurons.
11. Touch reception and proprioception.
12. Nociception.
13. Auditory system.
14. Vestibular system.
15. Anatomy and physiology of the eye.
16. Central visual pathways and circuits.
17. Motor neuron circuits. Spinal motor control.
18. Motor control of the brainstem and spinal cord.
19. Modulation of movement by the basal ganglia.
20. Modulation of movement by the cerebellum.
21. Eye movements.
22. Brain plasticity and memory.
23. Emotions.
24. Sleep and arousal.

During the examination, students have to demonstrate the knowledge of theories and facts in neuroscience. Students should be able to demonstrate the ability to discuss important topics and problems in the field of neuroscience, to understand relations both between course topics and with knowledge of other related fields including psychology, philosophy. Students should demonstrate the ability to appropriately use scientific terms in the field of neuroscience.

The final exam grading criteria are:
1. Compliance of the answer to the current question topic;
2. Sufficient volume of knowledge on the current question topic;
3. Ability to understand and discuss other topics within the course scope relevant to the current question topic;
4. Ability to logically organize the answer and to present evidence in adequate order;
5. Ability to correctly use scientific terms.

8. Methods of Instruction

The following educational technologies are used in the study process:

- Lectures involving continuous use of multimedia presentations and educational movies
- Seminars involving team oral discussions
- Tests, including two-choice tests
- Self-study of presentation
- Self-study of recommended literature

9. Special Equipment and Software Support (if required)

The course requires a computer or laptop, a projector, and acoustic systems for multimedia presentations and video.